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A Data Driven Approach to Reducing the Risk and Impact of Structure Fires

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Completed Research Paper

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Abstract

Structure (house) fires do not discriminate, they take life, injure, destroying property and damaging the environment. An average of 19,877 structure fires occurs annually in Australia at a cost of $3.3 Billion. Firefighting methods have largely remained unchanged since the Roman bucket brigades. Today, firefighters are still on standby and ready to respond (to a fire). This research highlights a disparate and uncoordinated body of knowledge with a clear gap in both the literature and practice. The research gap is the application of predictive analytics in the Emergency Management Sector that is to predict where and when a fire is most likely to occur. In this paper, sourcing two years of structure fire data combined with other datasets such as weather, we have shown predictive analytics could provide emergency managers with an Information System tool that would enable them to make informed decisions on future fire emergency scenarios. Using Activity Theory, we can demonstrate how Information System can be used as a tool to provide a safer community. The contribution of this research aims to use predictive analytics to identify at risk communities so that response time to fire-fighting can be decreased, and targeted fire safety education delivered.

Keywords: Structure Fire, Comprehensive Emergency Management Framework, Activity Theory, Prediction, Preparation, Mitigation, Response

Introduction

Structure fires (house fires) occur rarely, however, hold devastating impacts to the victims. With an average of 19,877 house fires occurring every year in Australia at a cost of $3.3 Billion (Commonwealth of Australia Productivity Commission 2015) to operate the corresponding response services, the question is will there be an opportunity to use tools and Information Technology (IT) and Information Systems (IS) to improve efficiency and effectivity of the firefighting industry?

Firefighting methods have largely remained unchanged since the Roman bucket brigades were depicted on Egyptian papyrus (200BC) (Kenlon 1913). With the digital disruption currently occurring, we have seen that industries do not necessarily want to change unless factors, such as economic and political, drive the evolution. Structure fires (house fires) rarely occur in a person's lifetime, but have a devastating impact to those that fall victim to it. When a fire occurs, it does not discriminate, it consumes all in its path taking life, injuring, destroying property and damaging the environment.

A fundamental principle of firefighting has remained constant throughout the centuries. Thus, Public Safety Agencies (PSAs) throughout the world are constantly on the process of standby, ready, and waiting to respond to when a structure fire occurs. Recent IT improvements, and the increased affordability of Business Intelligence (BI) applications makes Predictive Analytics (PAs) an accessible IS and IT tools which can be applied, as done in many industries, such as the military, police and retailers, to forecast scenarios that must be responded to. PAs enable managers to make better informed decisions on how to deploy financial and material resources to resolve a threatening event. It also helps mitigate damage caused to life, property, the environment, and the economy.

The capacity to predict where a fire is most likely to occur using PA would revolutionise the firefighting industry and save lives, property, the environment and the economy. The aim of this paper is to demonstrate a framework which uses PA techniques that could be developed to identify communities at high risk of structure fires. By using IS to identifying the locations of where there is a highly probability of a structure fire occurring, decision makers in PSAs could engage with those communities, to reduce and prevent the occurrence of a fire, or pre-deploy resources to high risk areas, hereby removing damage to human lives, property and the environment.

It would be a fire fighter's dream to forecast where a fire is most likely to occur using PAs. The aim of this paper is to demonstrate a framework using PAs techniques could be developed to identify communities at risk of structure fires. By using IS to identifying the locations of where there is a highly probability of a structure fire occurring, decision makers in PSAs could engage and educate those communities on fire safety thus reducing the likelihood of a fire occurring, or pre-deploy resources to a location that is closer to the higher risk areas thus enabling a faster response.

This paper is using a data driven approach to develop a PA framework that combines static and dynamic data to predict where structure (house) fires are likely to occur when certain weather conditions have combined on a particular day. The practical contribution of this paper is to inform PSAs the value of PA to identify risks before their occurrence and begin response to an event before it occurs as a prevention/ management strategy. This would enable PSA's to proactively engage with communities and could improve the management of resources, save lives and reduce costs before a disaster event occurs, whether this be a fire, a flood, power outages, or public riots.

Motivation of the Paper

In 2013, devastating fires impacted the town of Winmalee in the Blue Mountains of New South Wales (NSW), Australia, destroying 196 homes (Koperberg 2014). This prompted the then Chief Information Officer of Fire & Rescue NSW, the government agency responsible for structure firefighting in NSW, to question "… given all the information that is available to us, why we could not have foreseen what was about to happen and taken proactive action to prevent the loss of these homes …" (Host 2015).

A project was commenced with a large technology company to attempt to answer this question as a proof of concept. Local government areas from where the fires had impacted in the Blue Mountains had provided bushfire risk data on the all the properties in their areas. The Bureau of Meteorology (BoM) had provided 3-minute time slices of all the weather observations that occurred on the day of the disaster (17 October, 2013). The technology company developed a risk model that delivered its results via a web based Geographical Information Systems (GIS), and the output is shown in Figure 1.

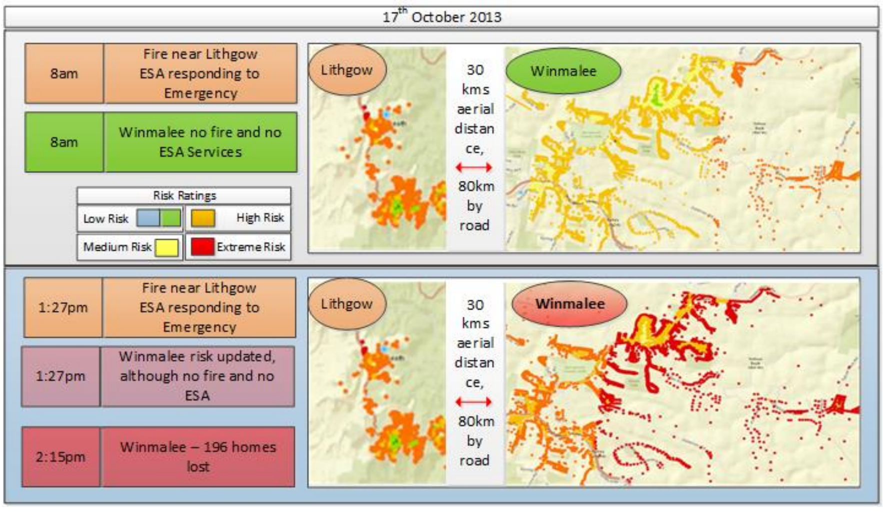

Figure 1. Output from the proof of concept risk model of the Blue Mountains bushfire (17 October, 2013)

The project was successful in modelling, however, there were some limitations regarding outcomes. It has been proven that the risk a fire presented to a property could be modelled and displayed visually.

It also showed that risks can change over time with changes in weather conditions, which see risks change from the morning (medium risk) to the afternoon (extreme risk). The key limitation with the output in Figure 1 was that weather observations were used rather than weather forecasts. In reality, the only data that would have been available in the morning to model the risk in the afternoon would have been the weather forecast. This limited the capacity of identifying potential risks ahead of time, and only facilitated of identity extreme risks. This removes capacity of pro-active planning and scheduling of resources to resolve the threat of a structure fire before its occurrence. Moreover, Fire Service Organisations are at their peak performance – there is no possible way that a fire appliance (truck) can physically get to a fire and extinguish a fire more quickly than what is occurring now.

Using the Thompson Routers Incites Journals Report (https://incites.thomsonreuters.com), a review of top ranking fire related journals demonstrated a fragmented body of knowledge that focuses mainly on the engineering aspects of fire prevention and usually in the bushfire (wildfire) domain. Moreover, the modelling is concentrated on bushfire; not very much modelling has been done in the structure (house) fire area from a practical perspective (see Jennings 1999, 2013). Thus, it was decided to refocus the project on structure firefighting and to identify if predictive modelling could be developed into an IS to predict where and when structure fires are likely to occur.

The Comprehensive Emergency Management Framework

Firstly, we need to understand the framework used by the emergency agencies, namely the Comprehensive Emergency Management Framework. The concept of Comprehensive Emergency Management was first described by the National Governors' Association in the United States (1979). This approach to emergency management is a core component used by many governments, public safety agencies and private companies throughout the world. It is the cyclical process of Prevention, Preparedness, Response and Recovery that accounts for the different phases (see Figure 2) of an emergency or disaster and how to manage these activities:

1. **Prevention/Mitigation** activities eliminate or reduce the probability of occurrence of a disaster. Examples include legislation, modifications to the built environment, and planning.
2. **Preparedness** activities extend mitigation activities but cannot prevent the occurrence. Examples include warnings, training, stockpiling and pre-deployment of resources.
3. **Response** activities occur in parallel as the disaster impacts. Examples include first response, medical care, shelter, feeding and search, and rescue.
4. **Recovery** activities aim to return an impacted area to the same or better circumstances than before the disaster impacted over the short, medium and long term. Examples include accommodation, clean up, loans, planning, and redevelopment.
5. **Reconstruction** activities occur over an extended period of time to rebuild societal infrastructure.

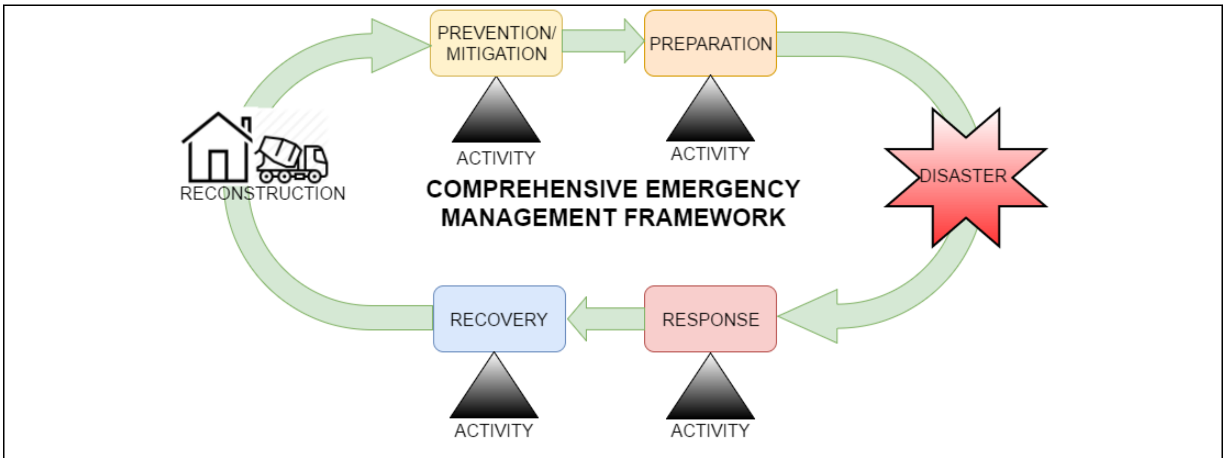

Figure 2. The Comprehensive Emergency Management framework (Modified from the State Governors Association 1979)

The Comprehensive Emergency Management approach describes the command and control arrangements, organisational structures, training and technical expertise required by personnel that operate in these different phases of the disaster management. In addition, by adopting an all hazards, all agencies approach to emergency management the interoperability problems identified by Allen (2014) should be avoided, however this is not the case in practice. The State Governors' Association stresses the importance of co-ordinating activities across these domains to reduce the impact of emergencies and disasters and incorporating a feedback loop to capture lessons learned.

However, the Comprehensive Emergency Management Framework has been challenged, labelled as an outdated concept, and not a truly comprehensive framework (see Cronstedt 2002). The main reason is the framework assumes sequentially between activities, creates barriers between the four activity elements and is overly focused on action activities (response). To overcome these limitations, Cronstedt (2002) suggests some changes that focus on real world outcomes, economics and accept risk treatments, whereas Kelly (1999) suggests software driven approach. In addition, Allen (2014) identified that there is a common theme emerging amongst researchers that a technology driven approach is required to improve the complexities that exist involving interoperability and collaboration during major incidents. This approach continues with the action based activities theme identified by Cronstedt (2002), and fails to address the need for preventative action to mitigate the likelihood and consequence of a disaster occurring. In fact, Allen (2014) also suggests that a technology driven approach could be a problem in itself.

In terms of research in the Emergency Management domain, most of studies have mainly done at the practitioner level where researchers aid practitioners to study emergency incident in terms of “fire service response times” (Challands 2010); optimise firefighting or emergency management community warning (Bunker et al. 2009, 2010); where emergency services should be located (Revelle 1989, 1995; Badri 1998; Gendreau et al., 2001) or despatched (Han et al. 2000). Other research focuses on the emergency response (Chen et al. 2008) and interoperability between Public Safety Agencies (Allen 2014); modelling socio economic (FEMA 1997; Chhetri et al., 2010; Ceyhan 2013); mathematical modelling (Rohde 2010); and use neural networks regressions to predict the numbers of fires in a locality (Yang et al. 2006). Risk management is operationally a significant tool for gauging the likelihood and consequences, and also used in risk mitigation (prevention) (Rosenberg 1999).

In addition, the current approach to dealing with a structure fire is to wait until it starts, which is a classic case of the ‘Response’ paradigm as noted by Allen (2014). A PSA is alerted, usually via phone, they then respond as quickly as possible to the location of the fire under lights and sirens travelling with all due haste. Thus, this paper reveals a gap of research in the area of preventing and predicting where and when structure fires are likely to occur based on the past response data. This leads us to our first research question:

RQ 1. What patterns can be found in structure fire response data?

Prediction and Fire Fighting in Information Systems

Governments invest a significant amount of resources in an attempt to reduce delays so PSAs can respond to emergencies at the first instance (Commonwealth of Australia Productivity Commission 2015). During a structure fire, timing is critical. The growth of a fire is exponential and a fire can consume a structure, in 6 minutes (Challands 2010; Host 2015) to such an extent that it cannot be recovered, rebuilt or reconstructed. The faster a PSA can respond will significantly reduce the consequences of a fire in terms of loss of life, damages to a property, the environment and economy. The key variable is time; how long firefighters have to save lives and a building, and how fast the fire grows to a point where lives and the building are inevitably lost. Therefore, if the PSA could forecast the occurrence and location of a future event then an alternative outcome could be achieved - valuable time could be saved in responding to the incident with a greater chance of saving lives and reducing impacts and damage to property, the economy and environment. Moreover, with enough advanced warning, an intervention such as community engagement and education could entirely prevent the forecast event (fire) from occurring in the first place.

In Information System theory development (Gregor 2006) describes prediction as the probability of an outcome given a certain set of conditions. Shmueli (2011) describes PAs as the use of models, methods and tools to create empirical predictions and the assessment of those predictions. Shmueli (2011) also notes an under representation of PAs in IS literature and presents a schema for the development of predictive models covering goal definition, data collection, data preparation, data exploration, variable, methods, evaluation, and use.

Decision Support Systems has been used to guide a user through a myriad of complex information with check points that can inform a user to make a decision (Silver 1991). Furthermore, the way information is presented and systems designed can influence the decision made by the end user (Silver 1991). Moreover, Decision Support Systems that leverage internal and external data sources can be used to assist by predicting outcomes based on various scenarios that enable users to make better informed decisions (Collins et al., 2010). The Information System itself can be referred to as a black box in that it explains the "why" not the "how" of what it is predicting.

This leads us to explore the use of IS to forecast a pending event avoids the inevitable delays and communications problems caused by issues relating to interoperability (Frale 2005; NIEM 2007; Chen 2009). This leads us to our second research question:

RQ 2. How can an Information System inform the prediction of structure fire?

Theoretical Grounding

IS researchers would agree with the straight forward claim that, "Activity Theory provides a lens to analyse the computer-supported activity of a group or organization and to study the design of artefacts for individuals and organizations" (Chen et al. 2013, p. 128). Most empirical IS research using Activity Theory applies the Engestrom Framework.

The use of Activity Theory as the conceptual framework of analysis is, "based on the idea that activity is primary" (Morf & Weber 2000, p. 81). "Activity Theory is particularly relevant in situations that have a significant historical and cultural context and where the participants, their purposes and their tools are in a process of rapid and constant change" (Hashim 2007, p. 2). Activity Theory was used by Chen (2013) to develop a data model with core standards across a modified Comprehensive Emergency Management Framework to assist in improving interoperability between first responders.

It has been suggested that fires are a human related problem and that many patterns reside inside the datasets concerning fire responses. The human brain is able to assess problems and identify patterns in a non-linear manner. The continued use by researchers of analysis tools such as regression, neural networks and decision trees. Moore's (1995) theory on Public Value is essential, but in evaluating benefits, it is difficult to measure due to a lack of strategy and understanding of the real ongoing costs of technology investment (Frisk 2015).

In the IS discipline, there is plentiful research on the use and application of analytical tools. Spangler (1999) discusses data mining as the search for patterns to make reasoned predictions using statistical methods to link variables. Yet, in a comparison of data mining methods to build predictive models using neural networks, decision trees and regression, no one method provides a foolproof result, and that a combination of tools should be used (Sinha 2015). Thus, when looking at relationships and trends in response data, it is not just using one method but a number of disparate methods might be required (Jennings 1999, 2013).

An Exploratory Study

First stage of the project is an exploratory study. We first used a dataset provided by Fire & Rescue NSW to analyse the data, and other datasets, which we believe are relevant, were added. The justification of the added datasets is presented in **Error! Reference source not found.**. The data was then analysed, and outputs were generated.

Data Collection and Limitation

A NSW structure fire dataset that was made available by Fire & Rescue NSW for the purposes of a data analytics competition was utilised for this research. This dataset contained 7,199 de-identified fire incident records, time of response, name and address were removed but post code was left to indicate the location of the structure fires that occurred over the two calendar years from 2012-2013.

In addition to this dataset, the weather conditions at the time the fire occurred along with Australian Bureau of Statistics Socio-economic Indexes for Areas data covering economic disadvantage, access to economic resources and education and employment, were supplemented and modified to align the locations of structure fires. A limitation, which has been accepted, is that actual observed rather than forecast weather data was used. The Economic data provided by the Commonwealth of Australia Productivity Commission (2015) for all fire agencies. The limitation is accepted and acknowledged, knowing that Bushfire agencies receive a separate funding source for bushfire fighting, and respond to structure fires in communities where there is no permanent fire brigade. The data used has been aggregated at the suburb and post code level. These datasets are summarised in **Error! Reference source not found.**.

Table 1. Other Datasets

Dataset	Details
Bureau of Meteorology (BoM)	Weather data, which has variables such as the minimum and maximum temperature, date, and time, was used to identify any patterns between weather factors and the NSW structure fire dataset.
Australian Bureau of Statistics (ABS)	Socio-Economic data which contains economic, resources, and level of education is to identify any patterns between socio economic indicators and the NSW structure fire dataset.
Commonwealth of Australia Productivity Commission	Aggregated structure fire response data and financial data are used to calculate the patterns between fire response and overall costs in the sector.

As this is an exploratory study and the size of the dataset is small, Microsoft Excel was used to analyse the data. All presentations for emergency agencies were all done using Excel. In future, when more data points are collected, other data analytics tools such as IBM SPSS, SAS Virtual Analytics or SAS Enterprise Miner, and SAP Business Object Lumira or SAP Predictive Analysis, will be utilised.

Analysis, Results and Findings

The data analyses were done in stages. First, we demonstrate the cost related to ‘response’ paradigm, which is continued to increase over years. Then, we associate the fire dataset with the forecast weather data. Next, we examine the number of fires relate to time of day, follow by investigative the number of fires associate with socio economic indicators. In the last step, we count the number of fires based on daily minimum temperature and the social economic indicators.

Expenditure

An analysis of data published annually by the Commonwealth of Australia Productivity Commission (2015) over the 10 years period 2004–2014 demonstrates increasing costs compared to relatively static levels of responses (see Figure 3). This evidence in shows over the ten-year period, the number of responses remain flat at 20,000 p.a., but a steady increase in funding (A$2.1Bn – A$3.3Bn) is required to maintain this level of vigilance. If we adjust for inflation over the same period at approx. 30%, it still represents a real increase in expenditure of over A$500M. This ‘response’ paradigm appears to represent a classic case in economics if the law of diminishing returns is that more and more funding is being spent in this domain (2004-2013) for the same level of response activity.

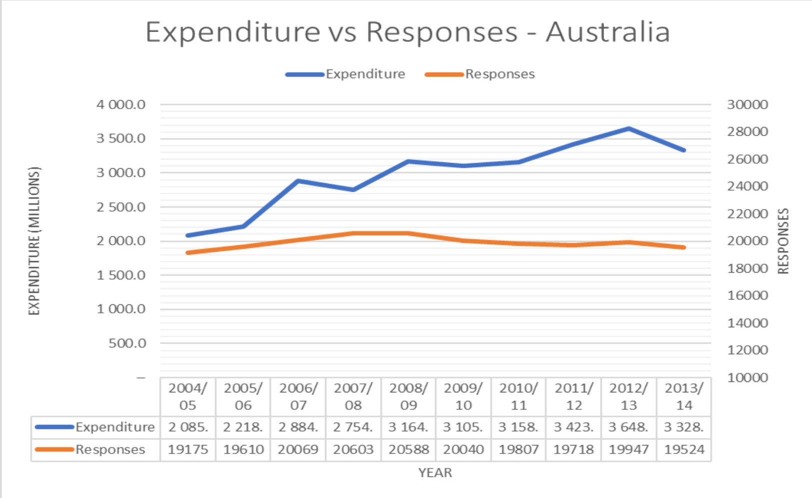

Figure 3. Expenditure vs Responses Fires Service Organisations 2004 - 2014 (not adjusted for inflation)

Weather (Temperature and Temperature Change)

When having informal discussions with the fire fighters, it was not uncommon for the fire fighters to describe the conditions of when they were more likely to have a busy day as opposed to when they would not. Hence, it was identified that weather (temperature) was a driving factor. This is supported by a simple pivot table analysis in Microsoft Excel in **Error! Reference source not found.**. A visual representation from which a trend can clearly be observed: more structure fire incidents on days with cold mornings (7^{o}C to 17^{o}C). These findings are comparable to those published by Corcoran (2009).

Table 2. No. of Fires compared to Daily Min. Temp. and Temp. Change

Count of Fires - Daily Minimum Temperature vs Temperature Differential

Rows: Daily Temperature Differential (Max - Min °C); columns: Daily Minimum Temperature (°C)

	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
0									4														5						9
1															3	5	6	9	2	5	3		1		1				35
2														7	2	8			10	7	7	29	7						77
3													4		2	9	1	10	13	17	11	17	13	2	4	2			105
4										4	3	4	19	4	13	11		14	10	33	32	31	31	20	5	1		2	237
5										2	14	29	6	11	15	26	21	28	23	45	30	32	24	12	9		1		328
6										2	40	20	35	19	32	20	23	38	31	26	31	31	32	25	14	3			422
7								1	9	42	23	53	30	37	33	32	47	25	33	50	65	39	46	36	9		1		611
8									12	9	40	29	60	41	52	34	43	40	28	77	60	61	23	11	4	3	2		629
9							6	11	17	39	67	45	66	37	50	48	49	58	54	39	63	25	22	11		3	4		714
10							2	13	14	18	42	45	69	60	49	30	53	39	55	49	33	24	2	2	4	11	3		617
11						1	10	33	30	62	44	65	46	62	30	35	41	22	20	19	22	20	27	13	13				615
12						13	8	42	29	64	73	44	40	17	53	15	25	18	25	21	18	20	16	2	10	3			556
13					1	14	26	22	14	32	15	36	25	30	27	24	37	28	17	8	15	15	3						389
14					4	19	27	22	33	28	18	20	10	34	14	8	40	27	23	20	6	23	8	3	4	1			392
15				4	23	21	25	20	15	29	19	21	16	17	22	21	15	6	13	9	12	7	10	5		3			333
16			1	11	29	19	9	25	13	19	14	9	11	16	7	8	16	19	4	6	8	7	6	1					258
17		5	9	12	15	13	29	9	21	13	13	14	7	22	8	5	15	14	4	12					2				242
18		1	6	3	11	7	21	5	12	10	12	7	6	8	14	6	1	9	2	4	7	8	2	5					167
19		8	1	6	25	6	9	8	8	7	6	4	12	10	5	10		9	6	5			3						148
20		2	9	6	10	4	3	9	7	3	6		1	9	7	1	2	2	2	2	2								87
21		2	3	1	8	4	12	6	1	1	4	6	2	2	1	9	14	2	1				3	1					83
22		1		4		3	3	3	1	3		1	5	3	1	6	3	1	4		3								45
23			1	4				1	2			3	5	5		2					1								24
24				4			1		6	1	4	3	5		4	4		2			2		4						40
25	2						2	2		5			1	2					3	2									19
26					1			1			1	1		1										2					7
27				2				2			3										2		1						10
Total	2	19	30	57	127	124	193	235	248	393	461	459	481	454	444	377	452	420	383	456	433	389	289	151	79	30	11	2	7199

The results from the gathered data indicate a seasonal relationship. A pivot table (**Error! Reference source not found.**) shows the number of fires by month, indicating that the cooler months of late autumn, winter and early spring (in Southern Hemisphere, winter is around the month of June) are when more structure fires occur.

An extension was made to the analysis to consider the time of day of the fire. The results revealed that late afternoon and early evening as being the busiest times which is likely to coincide with the times that people are coming home from work and cooking or heating appliance are being turned on. The findings align with informal discussions held with Australian fire fighters.

Table 3. Number of Fires – Time of Day by Month

Count of Fires - Time of Day vs Month

Hour of Day

Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
January	21	22	14	14	5	14	8	12	11	23	25	29	32	21	27	38	32	25	43	41	35	36	32	31	**591**
February	13	14	6	12	9	9	4	12	12	23	15	21	22	36	21	26	26	35	40	33	26	28	19	21	**483**
March	16	13	21	12	12	4	14	14	11	22	19	30	33	20	24	28	32	38	35	37	30	25	29	32	**551**
April	18	21	9	10	14	8	8	10	16	26	33	43	34	37	31	27	33	48	43	27	40	25	19	23	**603**
May	18	19	12	19	19	14	7	16	19	26	31	31	20	40	32	36	36	61	58	55	45	34	22	23	**693**
June	21	16	10	10	13	10	10	19	19	20	28	41	35	39	52	23	44	56	51	50	36	26	26	25	**680**
July	20	19	13	22	8	9	18	18	27	20	26	30	35	31	39	42	36	49	62	51	43	31	22	14	**685**
August	21	15	12	16	14	13	11	15	29	18	25	34	40	34	33	29	32	59	57	57	39	37	23	29	**692**
September	22	10	11	11	11	13	10	16	28	18	24	20	23	42	34	34	32	49	48	40	47	42	26	27	**638**
October	12	11	14	15	6	15	8	12	12	36	28	14	33	24	34	30	34	36	50	43	42	33	22	33	**597**
November	15	22	11	11	9	7	12	5	18	17	15	18	33	25	28	32	24	27	24	41	25	31	21	8	**479**
December	17	8	15	9	7	13	8	6	13	19	19	29	39	29	27	30	26	28	38	38	36	13	18	22	**507**
Total	**214**	**190**	**148**	**161**	**127**	**129**	**118**	**155**	**215**	**268**	**288**	**340**	**379**	**378**	**382**	**375**	**387**	**511**	**549**	**513**	**444**	**361**	**279**	**288**	**7199**

Human Factors (Socio Economic Indicators)

A correlation analysis of the three indicators (economic disadvantage, economic resources and education, and population) provided in the Australian Bureau of Statistics (2011), Socio-economic Indexes for Areas data cube by suburb. This aligns with Corcoran's (2009) findings.

- a negative correlation between the number of fires and economic resources, that is there are more fires as economic resources go down; and
- a positive correlation between population and number of fires, that is as population goes up so does number of fires.

A regression analysis was then undertaken comparing the count of fires compared to Economic Resources to develop a trend line to see if structure house fires could be forecast.

y = Count of Fires = 1614 – 163 * Index of Economic Resources

The regression statistics show an R Square value of 0.828, indicating a good alignment of the trend line to the actual data to use as a predictive tool and the Analysis of Variance (ANOVA) indicates that the results are significant and within tolerances being confirmed by the F Value (0.000). P Values (0.000 and 0.000) support the F Values and allowing the derivation of a trend line that can be used to assist in the prediction of structure fires.

Furthermore, we compare the trend line of predicted fires versus actual fires, as shown in Figure 4 across the 10 levels of economic advantage, with level 1 being the lowest and 10 the highest. This seems to indicate that fires could be readily predicted (but not all fires) for the lower three socio-economic deciles. This supports the previous findings by Jennings (1999, 2013) and Corcoran (2009). It shows there is a relationship between the instances of fire and lower socio economic resources.

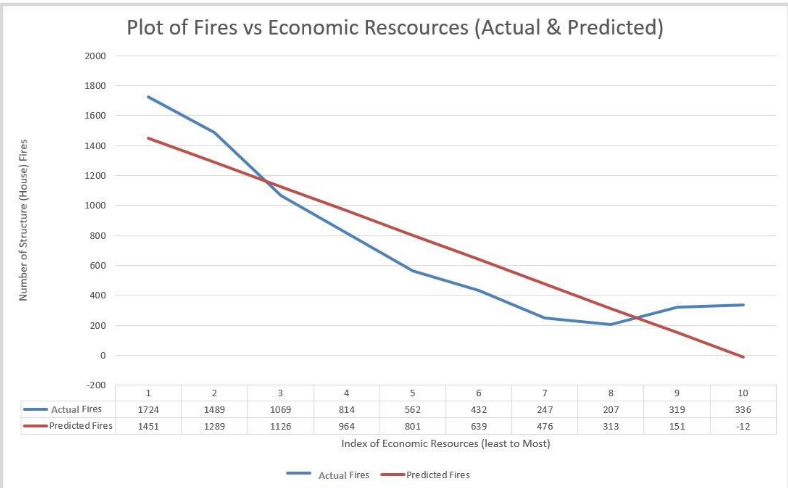

Figure 4. Plot of Fires vs Economic Resources (Actual and Predicted)

Weather and Economic Indicators

Data primarily identifies that more fires are likely on cold days (see **Error! Reference source not found.**). Figure 4 identifies the lower three socio-economic deciles are at higher risk of structure fire. A further analysis between temperature and socio economic indicators in **Error! Reference source not found.** supports the findings of cold weather and economics (Corcoran 2009) that the lower three socio-economic deciles are at higher risk of structure fire on lower temperature days. The analysis reveals that there are more instances of structure fires in lower socio-economic areas; on cold days when there is a small temperature differential (increase); during late autumn, winter and early spring; and in the late afternoon and early evening.

Table 4 Count of Fires – Daily Minimum Temperature and Economic Resources

Count of Fires - Daily Minimum Temperature vs Economic resources

Daily Minimum Temperature (columns) / Economic Resources (rows)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	**Total**
1		11	15	22	63	81	106	134	146	177	137	136	121	96	115	76	60	57	39	43	27	18	13	8	11	7	2	3	**1724**
2	2	3	15	23	38	82	83	114	143	137	120	127	123	80	75	63	58	57	47	37	17	16	10	5	3	5	2	4	**1489**
3	3	9	11	16	32	42	63	100	80	103	114	99	80	56	53	49	35	38	29	15	7	12	8	6	5	1	1	2	**1069**
4	1	5	10	7	28	39	42	66	64	89	78	72	62	45	55	33	29	21	18	13	9	13	2	3	7	3			**814**
5	1	3	11	10	27	26	43	53	52	53	44	42	44	23	25	30	21	16	10	15	7	1	1		3	1			**562**
6			1	9	10	9	27	46	43	44	37	35	32	32	22	25	19	7	5	8	9	6	4				1	1	**432**
7	1	3	4	5	8	9	9	16	29	26	18	26	22	12	11	15	5	11	6	2	5	2			1	1			**247**
8			4	1	7	13	10	20	14	26	21	22	11	13	7	13	7	6	3	3	1	1	1		3				**207**
9	1	1	3	7	12	14	19	28	29	33	26	25	26	13	12	17	12	13	6	6	2	8	3		1	1	1		**319**
10			3	5	12	13	20	34	29	26	22	31	35	19	17	12	12	16	4	6	3	6	3	2	6				**336**
Total	**9**	**35**	**77**	**105**	**237**	**328**	**422**	**611**	**629**	**714**	**617**	**615**	**556**	**389**	**392**	**333**	**258**	**242**	**167**	**148**	**87**	**83**	**45**	**24**	**40**	**19**	**7**	**10**	**7199**

Economic Indicators and Fires

The number of fires by economic indicator decile reveals that the lower deciles are greatly over represented when compared to the higher deciles (see **Error! Reference source not found.**). This echoes the patterns identified in Figure 4. Using the common measure of fires per 1,000 people, it clearly demonstrates there are more instances of structure fires in the lower socio-economic areas.

Table 5 Count of Fires vs Economic Indictor Deciles

Decile	Number of Fires	Population	Fires Per 1,000 Population
1	1,724	928,710	1.86
2	1,489	1,086,491	1.37
3	1,069	956,150	1.12
4	814	1,072,448	0.76
5	562	747,919	0.75
6	432	621,342	0.70
7	247	433,888	0.57
8	207	469,694	0.44
9	319	536,031	0.60
10	336	875,295	0.38

Discussion

Relationships between factors

The small number of factors examined in this paper that appear to contribute to instances of structure fire demonstrate a complex relationship (Benbya and McKelvey 2006; Simon and Cilliers 2005). Visually relationship can be observed in the Data, Tables and Figures. However, more statistical work is required to further explain these relationships, such as using linear and non-linear techniques, in order to develop a new model that could be used within an Information system to predict future instances of structure fire. This is the next stage of the project.

Activity Theory allows the development and understanding of the application of the Comprehensive Emergency Management framework in past incidents, and expands it into the complex process of predicting and planning the location of future fire scenarios. In the complex realm of fire prediction, Activity Theory (Figure 5) can help make sense of the issues and inform the development of a predictive model. Now, IS becomes part of the tools used to fight fire (See under 'Tools' in Figure 5). Most significantly it demonstrates that IS expertise can contribute to an understanding of the problem in detailed fire predictions and that practitioners can understand the Activity Theory.

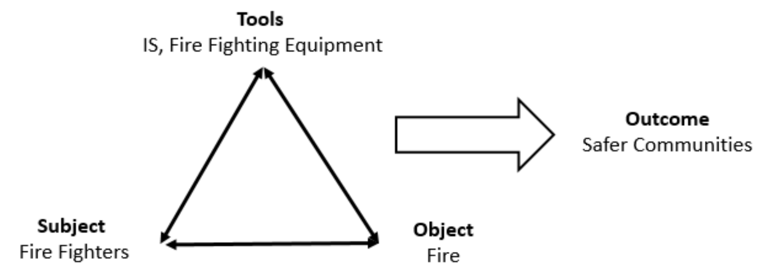

Figure 5. The Engestrom Activity System of a Fire Prediction Framework

We have concluded that IS skills and resources to integrated the vastly different data sets, and the development of PAs for modelling the prediction of fire scenarios and their pattern. Activity Theory has informed the various activities that influence fire prediction are:

- People are usually the source of a fire,
- What tools people use can create fires,
- Weather conditions can produce factors that create fires,
- Socio demographic factors contribute to the conditions that create fires,
- Environmental (temperature, day of the week and time of day), and
- Financial factors can create conditions that produce fires.

The resulting patterns in data answers the RQ 1 by demonstrating that there are more instances of structure fires in lower socio-economic areas; on cold days when there is a small temperature differential (increase); during late Autumn, Winter and early spring; and in the late afternoon and early evening. Further research into these patterns would be significant, specifically using a larger dataset to develop a predictive model.

For RQ 2, the data in Tables 2, 3 and 4 supported the notion that an Information Systems could be used to forecast the circumstance where structure fire is likely to occur which would greatly enhance societies ability to prepare for and respond to these emergencies. It is evident that the development of an Information System is required to further study the relationships between the identified factors. Using an Activity Theory lens the output available to emergency managers could be used in making decisions on resource deployments and community engagement, education and warning activities.

Proposed Change

The current approach in dealing with a structure fire is to wait until it starts, then alert a Public Safety Agency, usually via phone, they then respond as quickly as possible to the location of the fire under lights and sirens travelling with all due haste to hopefully extinguish it before there is loss of life, injury or significant damage to property or the environment. This was no different to the bucket brigades from centuries ago. Even the current practice of smoke alarms, the fire fighters still have to wait for the fire to start before respond.

The issue being that there is an highly unionized workforce with an entrenched culture that focuses on response (Nickel 2012) with any suggestion of changing the way firefighting may be managed, particularly by using Information Systems is likely to be met with great scepticism and resistance.

Towards development of a Predictive Framework

Using an Information System would enable Public Safety Agencies to place more resources on stand-by where they may be needed, relocated resources to locations to enable a quicker responses and to optimize overall human and material resources to obtain the best economic payback for the community in saving life, property, economic and environmental damage.

Information such as geo-spatial data, socio economic and demographic indicators, consumer purchasing data, marketing data, social media, past history, of fire incidents could be used to create risk profiles that identify areas of higher than average risk.

It may be possible to combine these static risk profiles with dynamic data such as weather forecasts creating a framework for dynamic PAs. This would enable at least seven days (based on weather forecasts) advanced notice on areas that are at a higher level of risk.

The development of a Predictive Frameworks could then be extended to provide best case, likely case and extremely chaotic (also known as 'black swan') scenarios with estimates provided for each that considers a triple bottom line encompassing potential loss of life or injury, damage to property, economic and environmental impact. The data suggests that a particular set of conditions (cool days with small temperature increases across the day) act as an initial trigger for structure fire. Combined with factors such as socio economic indicators, historical incident response, planning and build environment data the outputs from such an Information System could be used in multiple ways by providing base line data feeds tailored for different audiences.

Conclusion

Structure fires are a rare, but deadly when it happens. We have examined structure fires and the application of PAs application software with the aim of answering the two following questions:

RQ 1. What patterns can be found in structure fire response data?

RQ 2. How can an Information System inform the prediction of structure fire?

In summary, RQ 1 has been addressed by the analysis undertaken with the results in Figures 2 and 3, which show the strongest patterns between the instances of structure fire, socio economics, time of year, time of day and weather conditions. This confirmed that there are patterns in the collected data that can identify where there is a higher probability of a structure fire occurring. This will most likely occur on days of low (morning) temperatures, in lower socio-economic areas, during the late autumn, winter and early spring, and during late afternoon and early evening.

This information, much of which is intrinsically known by firefighters, once constructed into an Information System (RQ 2) could be used to inform decision making to improve community safety through a number of avenues – by using weather forecasts, predictions of at risk communities could be made up to one week in advance. This would enable organisations to proactively engage with and educate at risk communities. Warnings could also be targeted to at risk communities.

Research is this domain to develop a predictive framework for structure fire emergencies is likely to disrupt the current approach used by Public Safety Agencies by shifting focus from action activities (Response) to Prevention activities with an aim to save time, lives and cost by approaching the problem from an alternative real world lens. Nevertheless, this does not mean that we do not need firefighters ready to response, as a toolset this could be used by firefighters to better use their resources to keep us safe. Further research into these patterns using a larger dataset to develop the Information System would be a worthwhile activity.

Potential Ethical Implications

The construction of such an Information System will give rise ethical considerations. Knowing that one area is at higher risk than another and not taking any action could be deemed to be an ethical issue. Presently all levels of government are in possession of information that identifies at risk communities, properties and individuals across a variety of domain in which the government has an option to do something or nothing. This is not solely in the emergency and disaster management domain and could be the subject of further research.

Future Direction

Structure fires are rarely occurring phenomenon that has a devastating impact on those impacted by it. Firefighting principles have generally remained unchanged for centuries. Predictive Analytics is a common used tool in many industries that may have application in the disaster and emergency management domain. There may be application to develop models for an Information System using real time data, such as weather forecasts being used as an input into models that calculate risk across multiple scenarios to enable Public Safety Agencies to make informed decision on future resource deployments and education and engagement activates for those most at risk of structure fire.

This research could be extended to consider modification of the Comprehensive Emergency Management Framework by adding an additional component of 'Prediction' as a new major element of a component embedded within the existing framework.

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